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A CONSULTANTS REVIEW OF THE LOS ANGELES-LONG BEACH HARBORS STUD--ETC(U)
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A CONSULTANTS REVIEW OF THE LOS ANGELES-LONG BEACH HARBORS STUDY

by

Robert O. Reid, Robert G. Dean, Leon E. Borgman

Hydraulics Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

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August 1977

Final Report

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14 WES-MP-H-77-10

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
Miscellaneous Paper ~~H-77-10~~

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
6 A CONSULTANT'S REVIEW OF THE LOS ANGELES-LONG BEACH HARBORS STUDY.

5. TYPE OF REPORT & PERIOD COVERED
9 Final rep[redacted]t.

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
10 Robert O. Reid, Robert G. Dean, Leon E. Borgman

8. CONTRACT OR GRANT NUMBER(s)
DACW39-75-C-005
DACW39-76-C-0013
DACW39-76-C-0014

9. PERFORMING ORGANIZATION NAME AND ADDRESS
U. S. Army Engineer Waterways Experiment Station
Hydraulics Laboratory
P. O. Box 631, Vicksburg, Mississippi 39180

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS

12. REPORT DATE
11 Aug[redacted]77

13. NUMBER OF PAGES
23
12 25p.

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited.

DDC
SEP 2 1977
C

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Harbors
Long Beach Harbor
Los Angeles Harbor

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
A consultant's review of the Los Angeles-Long Beach Harbors Study was performed by Professor Robert O. Reid of Texas A&M University, Professor Robert G. Dean of the University of Delaware, and Professor Leon E. Borgman of the University of Wyoming. The review primarily covers the acquisition and analyses of prototype wave and ship motion data. Comments and suggestions are offered regarding improvements and methods of attack for the present and future studies of this type.

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SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

PREFACE

The consultants review reported herein was performed by Professor Robert O. Reid (contract no. DACW39-75-C-005) of Texas A & M University; Professor Robert G. Dean (contract no. DACW39-76-C-0013) of the University of Delaware; and Professor Leon E. Borgman (contract no. DACW39-76-C-0014) of the University of Wyoming.

The consultants were briefed and intensive discussions were held with personnel of the Hydraulics Laboratory on 17-19 November 1976. This report was prepared as a result of and subsequent to this meeting.

Personnel of the Hydraulics Laboratory involved in the 17-19 November meeting were Mr. H. B. Simmons, Chief of the Hydraulics Laboratory; Mr. F. A. Herrmann, Assistant Chief of the Hydraulics Laboratory; Dr. R. W. Whalin, Chief of the Wave Dynamics Division; Mr. E. B. Pickett, Chief of the Hydraulic Analysis Division, Mr. C. E. Chatham, Chief of the Harbor Wave Action Branch; Dr. D. L. Durham and Mr. D. G. Outlaw of the Harbor Wave Action Branch: Mr. J. R. Houston of the Wave Research Branch; Dr. J. J. Wanstrath, Dr. D. T. Resio, and Mr. A. W. Garcia of the Coastal Branch; Mr. H. L. Butler of the Wave Dynamics Division; and Mr. W. H. McAnally of the Harbor Entrance Branch.

Commander and Director of WES during preparation and publication of this report was COL John L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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CONTENTS

A CONSULTANTS REVIEW OF THE
LOS ANGELES-LONG BEACH HARBORS STUDY

by

Professor Robert O. Reid, Texas A & M University
Professor Robert G. Dean, University of Delaware
Professor Leon E. Borgman, University of Wyoming

Introduction

The prototype wave and tide data collection, the various numerical computer analyses, and the physical model studies altogether comprise a remarkable and comprehensive investigation of conditions in the Los Angeles and Long Beach Harbors complex. The personnel involved are to be complimented for their extended effort and careful thought in carrying out the elaborate details and logistic complexities of such a major project.

As always in a complicated investigation, questions arise in the course of the study which cannot be thoroughly investigated at the time due to the pressure of deadlines and other practical considerations. Also, improvements in project organization become obvious as experience is accumulated. The following comments are offered as a means of making explicit such improvements and outlining methods of attack on some of the questions which arose.

The ideas expressed in the following paragraphs were developed in several days of intensive discussions between the authors and the WES research personnel. It is difficult to assign authorship for any particular improvement or proposed research procedure because of the active interchange of ideas involved in the discussion. The authors support the conclusions expressed, however, and accept responsibility for their inclusion in the report.

1. Measurement of Prototype Ship Motions

a. Discussion

A key element in the study of ship surging is the acquisition of quantitative prototype motion data from moored ships. Ideally, when a vessel enters and is moored in an area susceptible to ship motions, it would be desirable to place a self-contained instrument package aboard which would record motion characteristics. Consideration should be given to the development of such a system for future studies. Perhaps limited measurements can be performed in studies in the near future and results, including extent and period of motion, would be extremely useful.

Several possibilities of varying degree of complexity exist for measurements indicating ship motions. Some of these systems could be developed in a self-contained package. One possibility is the measurement of ship surging through the use of a sonic distance transducer. Such devices are currently used for wave gages and in the proposed application the transducer and receiver could be mounted on the wharf and "beamed" horizontally to a temporary target attached to the vessel. Alternatively, a rotary "distance" transducer could be mounted on the wharf; the rotary transducer would be displaced by a string passing over a pulley and attached (horizontally) to the vessel with tension provided by a weight hanging vertically from the other end of the string. Methods exist to monitor the tension in heavy lines and these could be used as an indication of ship motion. Similarly, a load cell connected in series with a "soft" spring capable of considerable elongation attached to the ship and wharf would provide a measure of displacement. One of the simplest methods of sensing surging would be a time-lapse camera which could monitor the ship movement via ambient light during the day and a light source affixed to the vessel during the night.

b. Implementation

Instrumentation of the type discussed above could yield ship motion data of substantial value in future similar studies.

2. Ship Motion Prediction for Current Studies

a. Discussion

It appears that the fluid kinematics from the physical model or from the numerical simulations could be introduced into the differential equation numerical solution to produce predicted ship motion, at least for selected ship and mooring line combinations. This would be quite valuable as quantitative information which supplements the visual observations of ship motion previously gathered.

b. Implementation

Studies of this type are recommended as additional work in connection with the Los Angeles-Long Beach Harbors investigations. Work along this line would be quite useful also as background for planning the collection of quantitative ship movement data in future prototype studies.

3. Potential for Ship Surging

a. Discussion

In order to establish the relative range of ship motion for various areas in Los Angeles and Long Beach Harbors, it is recommended that the existing wave data be combined with a simplified surge response function to obtain the potential for ship surging. East Channel will serve as an example.

Given one of the more energetic wave spectra, $S_{\eta\eta}(\omega)$, in East Channel and a simplified (linearized) surge response function, $R(\xi,\omega)$, vs position ξ along East Channel for a ship of representative length, ℓ , the spectrum of ship surging, $S_{xx}(\xi\ \omega)$, can be computed as

$$S_{xx}(\xi,\omega) = |R(\xi,\omega)|^2 S_{\eta\eta}(\omega)$$

The potential for surging, P_x , should be proportional to the square root of the surging energy, for example

$$P_x(\xi) = \sqrt{\int S_{xx}(\xi,\omega)\, d\omega}$$

Where the integration extends over all frequencies of significant surge energy.

In the development of the potential for ship surging, it would be possible to utilize various degrees of complexity for the response function $R(\xi,\omega)$. For purposes here, it is recommended that a very simple result be used, such as that obtained by considering an unrestrained and undamped ship of rectangular planform restrained in a horizontal attitude in a standing wave field,

$$|R(\xi,\omega)| = \frac{g}{\omega^2} \frac{\sin \frac{\kappa\ell}{2}}{\frac{\ell}{2}} |\sin \kappa\xi|$$

where ξ is the distance from the closed end of East Channel and κ is the wave number.

The comparison of $P_x(\xi)$ for different locations along East Channel and for different berthing areas should be useful. This type of result

could also be used in an effort to "detune" a ship's mooring system from the natural oscillation tendencies in a particular area. For example, by plotting the normalized cummulative spectrum, $C_{xx}(\xi,\omega)$

$$C_{xx}(\xi,\omega') = \int_0^{\omega'} S_{xx}(\xi,\omega)\,d\omega$$

and noting frequencies corresponding to steep gradients to C_{xx}, it may be possible to guide the evolution of mooring systems which will minimize surging problems.

b. Implementation

The foregoing discussion is directed primarily toward the Los Angeles-Long Beach Harbors Study; however, the methodology should be equally applicable to other similar future studies.

4. Time-Varing Spectral Densities

a. Discussion

The overlapping interval, psuedo-stationary approach to the estimation of time-varying amplitude spectral densities is reasonable as a first approximation. However, it might be desirable to carry the problem one step further and to evaluate the time-varying spectral densities by several other techniques which are specifically oriented towards non-stationary time series. This would permit direct comparisons of the estimates and an evaluation of their precision.

It is recommended that an initial comprehensive review of methods for estimating spectral densities in non-stationary processes be undertaken as a part of the project. However, several possible techniques come to mind: (1) The time series could be processed with band pass filters centered at each of several frequency bands. The time-band-averaged variance of each output would provide an estimate of the time-varying spectral density at the band midpoint. (2) The time series might be represented by the discrete Fourier series

$$\eta(n\Delta t) = \Delta f \sum_{m=0}^{N-1} [A_{om} + tA_{1m} + t^2 A_{2m} + \ldots] e^{+i2\pi mn/N}$$

and various procedures used to estimate the frequency function A_{om}, A_{1m}, A_{2m}, . . . In particular, if only A_{om} was non-negligible, the psuedo-stationary approach would appear adequate. (3) Finally methods of complex demodulation, which are analogous to Item (1) above might be used.

b. Implementation

The application of non-stationary time series analysis procedures to representative data sets of the Los Angeles-Long Beach Harbors investigations should allow precision of the associated spectra to be estimated without an excessive commitment of time or funds.

Studies of this type would be of basic importance in planning the analysis of new similar investigations. The pseudo-stationary analysis procedure could be introduced if it were more appropriate. Thus, the study of procedures for estimating time-varying spectra could be justified

as additional research studies or as a part of future prototype data acquisition and analysis.

5. Error Analysis Spectral Estimates

a. Discussion

Confidence intervals for spectral estimates given in the WES reports are generally based on the standard and well-known chi-squared statistics. The validity of such intervals depends on the spectra being nearly "flat" and the time series being Gaussian. In addition, the situation is further confused by smoothing and filtering procedures applied in the data analysis and by any non-stationarity present.

The confidence estimates given in the report are certainly valid as indices of reliability and their use is quite common in reporting time series spectra. However, further study is often helpful as a means of determining how accurately the chi-squared bands function as precise confidence intervals.

One procedure that may be used to investigate this behavior is based on statistical simulation. A Gaussian time series with a known time-varying spectral density approximating that for the data can be computer simulated by any one of several procedures. (Frequency-domain simulation is generally, by far, the fastest method.) Then, the resulting time series can be processed with all the smoothing and filtering imposed on the actual data. The spectral estimates produced can be compared with the original "true" spectral density used in the simulation. Fifty to a hundred such simulation runs can be used to ascertain the confidence interval and bias of the total estimation process. The deviations from chi-squared behavior and the determination and the estimation bias both can thus be directly evaluated.

A more detailed error analysis may help resolve questions concerning the significance of low level "bumps" in the data spectral densities. If simulations with "true" spectral densities which do not contain a particular "bump" lead to estimates with the "bump," the estimation procedure must be producing the feature in question by side-lobe leakage from nearby peaks or by other data-manipulation peculiarities. If the "bump" is produced consistently and if that same feature is present in the "true" spectral density input, then the "bump" most likely represents real behavior.

b. Implementation

It appears worthwhile to make studies of this type for the Long Beach-Los Angeles Harbors spectral estimates as an error analysis and control phase. Future studies might well automatically incorporate such procedures in the routine processing of the data.

6. How Typical Was The Prototype Data Year?

a. Discussion

Some determination of the relative severity or mildness of the wave conditions off Southern California during the data collection interval would be highly desirable. Since the physical model is calibrated against the prototype data year, any interpretation of long term ship movement statistics would require knowledge of the relative severity for that year. Ideally, recordings of low frequency waves in the general range of the ship motion frequences would be used if they can be obtained from some source up or down the coast. There is some basis for trying to recover information on very long period waves from the high frequency portion of tide records.

Perhaps year-by-year logs of ship movement problems from the Port Authorities could be obtained. If nothing this detailed is available, interviews with long term employees at the Port might be used as a last resort to place the prototype data year into context with other years.

Also weather records for the year of observation could be compared with other years to see if the storms were generally less intense than average.

b. Implementation

Although the above discussion is primarily framed in terms of the Los Angeles-Long Beach Harbors study, it is recommended that the acquisition of such data be an integral part of future prototype studies.

7. Evaluation of Frequency Dependent Harbor Transfer Functions

a. Discussion

As a means of intercomparing the results of the prototype wave measurements with those of the physical model and with results of the numerical model, it is recommended that the complex transfer functions (magnitude and phase) of the responses at all harbor gages be determined using one of the port gages as a reference (either Gage 10 at Angels Gate or Gage 4 at Queens Gate).

b. Implementation

Sample estimates for these transfer functions can be evaluated by cross-spectral FFT analysis of a given gage with the reference gage for sample periods (such as the 6+ hour samples employed in the spectral estimates in the case of the prototype). Assuming that the water level variations at all points along the breakwater and in the harbors are well correlated (highly coherent) for each frequency, as in the case of the physical model, then the estimates of the transfer function for a given gage of the prototype should represent random samples of a common function. In this case, reliable estimates could be obtained for the transfer functions by averaging at fixed frequencies across the ensemble of sample estimates.

In the case of the physical model and numerical model the transfer functions relative to the selected reference position should be much more straight forward. It is recommended that the gages in the physical model be taken to correspond as closely as possible with those locations employed in the prototype. The transfer functions determined from the prototype should be compared with the corresponding functions determined from the physical model and the numerical model. It is not expected that the latter will correspond with either of the other two except for location of resonant peaks, because of the absence of frictional damping in the present numerical model. Possible differences between prototype and physical model could reveal alternate sources of wave energy.

In future studies, it is recommended that an attempt be made to locate wave gages well offshore of the harbor and that such gages be used as references.

8. Alternate Sources of Long Wave Energy

a. Discussion

It is assumed in the Los Angeles-Long Beach Harbors physical model studies that the sole source of wave energy in the band 15 sec to say 20 min is from the open sea to the south of the harbor. Indeed, probably the majority of the shorter period energy (say less than 1 min) derives from this source and is probably well simulated by the existing wave generator arrangement. Certainly some long wave energy may also be incident from the south. However, it is also feasible that long wave energy in the form of trapped shelf modes (edge waves) could arrive from the east into the Los Angeles-Long Beach Harbors regions. The presence of such energy would produce differences in the response deduced for the prototype and that for the physical model. Hence, the possible existence of such an alternative energy source should be investigated.

b. Implementation for the Existing Prototype Data

One way of detecting the possible existence of energy from independent sources of distinctly different directions is to carry out the evaluation of coherence between the gages at Angels Gate and that at Queens gate. This requires a cross-spectral calculation based upon simultaneous samples of the records at these gages. For the physical model such calculations should show coherencies of unity or close to unity. Any significant departure of coherence from unity based upon the prototype data would indicate possible additional sources of energy at those frequencies having low coherence.

9. Evaluation of Directional Sensitivity In Numerical and Physical Models

a. Discussion

In the present Los Angeles-Long Beach Harbors Model Study, considerable effort has been made to ensure that the generated crests of long waves in the model correspond to those obtained through refraction procedures for wave energy originating from the South. It would be useful to determine the sensitivity to incident wave direction of the wave response at various locations in the harbor. Such information would serve to indicate the relative importance of careful placement of the wave makers in the model and also may assist in determining the source(s) of long wave energy in the prototype. As examples, if, for long period waves, it is found that the responses to long waves are sensitive to incident wave directions, it may be possible to infer from the prototype data whether or not a rational explanation of the long waves would require more than an offshore source (for example, edge waves could be a possible source).

Similar sensitivity studies could be carried out via numerical modeling and would provide a measure of confirmation between these two methods.

b. Implementation

The evaluation of directional sensitivity would be of immediate value to the Los Angeles-Long Beach study and should also be useful in future similar model studies in establishing the general requirements of wave-maker configuration.

10. Spectral Excitation of Physical Models (i.e. Irregular Wave Trains)

a. Discussion

There are at least three reasons to consider generating irregular waves in the physical model:

1. It may be possible to expeditiously develop the response function at various locations in the model for a broad range of frequencies. In addition, it may be possible to evaluate directly the statistics of waves.

2. By generating a narrow band of wave energy (swell), it will be possible to determine whether the modulation of these waves in the form of wave trains could provide a source of long wave energy. Although the mechanism resulting in the long-period energy is not clear, possibilities include transmission through the breakwater and/or reflection and amplification of second order waves in features of the harbors.

3. Comparison of the model wave spectra obtained from locations inside the breakwater with those from the corresponding prototype gages should assist in evaluating the suitability of a single wave-maker location for a broad range of frequencies and also should allow the incident prototype wave spectrum to be inferred.

b. Implementation

The present Los Angles-Long Beach Harbors model is probably one of the first of this general size and scope in which the capability exists to generate irregular waves. As noted, such a capability is valuable in evaluating the possibility of various mechanisms for generating long wave energy. The potential of this capability for expediting and enhancing the usefulness of this type of model study should be explored in the present study and incorporated into plans for future studies.

11. Numerical Tidal Model

a. Discussion

The results of Butler's implicit numerical model including net circulation as compared with the results of the physical model for both existing and proposed changes in the Los Angeles-Long Beach Harbors look very encouraging in the sense that the numerical model is capable of resolving features which heretofore have not been economically feasible.

b. Possible Improvement

In the discussion of the mathematical basis for the numerical model given by Butler and Raney (1976)* the convection terms in the equations of motion for the volume transport are given in the nondivergence form ($\frac{U}{d}\ \partial U/\partial x + \frac{V}{d}\ \partial U/\partial y$) and similar for V . These should be employed in the divergence form in these equations (i.e., $\partial(UU/d)/\partial x$ and $\partial(UV/d)/\partial y$, etc) as for example in the model of Leendertse.

The present form employed can lead to errors and in the absence of friction will tend to create non-linear instability. It is suggested that suitable changes be made to correct these terms, if indeed the coded program follows the written discussion.

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* ARO Report 76-3, Proceedings of the 1976 Army Numerical Analysis and Computers Conference, pp. 393-411.

12. Development of Prototype Wave Data in A Form Readily Used by Others

a. Discussion

The wave data collected in the field program of the Los Angeles-Long Beach Harbors study are unique in their quality, geographic coverage, duration, and completeness. Undoubtedly, the engineering and scientific potential of these data not only fulfills but extends well beyond the immediate objectives of the present project. Moveover, the future development of the Harbors would benefit through additional analysis and interpretation of these data which will undoubtedly be of interest to a number of individual investigators and agencies. It is, therefore, recommended that the data be demultiplexed and stored on magnetic tapes in an optimum tape format for deposition to and use by interested parties. Also, a User's Manual for these tapes should be developed.

b. Implementation

The organization of the Los Angeles-Long Beach prototype wave data in the manner discussed above should also serve as a test format for storing and making available sets of extensive field data resulting from future studies.

13. Evaluation of Refraction Calculations

a. Discussion

Standard refraction calculations were extensively used in the planning of the Los Angeles-Long Beach model and in the conduct of the test program. Moreover, such calculations are prominent in planning all of the models and in the analysis of wave effects over variable bathymetry. Unfortunately, there is little basis to assess the validity of such refraction calculations and, in fact, there are considerable reservations concerning their use among coastal and ocean engineers.

The previous refraction calculations and the Los Angeles-Long Beach Harbors model provide an ideal opportunity to conduct a definitive evaluation of the validity of standard refraction calculations. In particular, refraction calculations for long waves have indicated a substantial concentration of wave energy seaward of Queen's Gate and the model wave maker has been positioned to approximately replicate a wave-crest configuration considerably seaward of this location of wave energy concentration.

It is recommended that measurements of the "wave field" be made to establish "experimental" refraction coefficients for comparison with those based on calculation. The area of indicated wave energy concentration should receive special attention.

b. Implementation

The evaluation recommended above would be of general value to coastal and ocean engineering practice and, in particular, to model planning and conduct.

Appendix A

While the following two items do not apply directly to the Los Angeles and Long Beach Harbors Project study, they are included for possible future application to studies of this type.

1. Possible Extensions of Numerical Model for Wave Response

a. Discussion

It is recommended that studies, falling in the category of basic development but intended for application in future harbor studies such as those for Hilo, be initiated with respect to possible generalization of the existing finite element numerical wave model. Specifically, it appears very desirable that bottom friction (at least in a linearized version) should be incorporated in the numerical model. Also, a generalized model which allows for dispersion is essential for those studies where short period waves are important (as might be the case for Hilo). Neither the long wave non-dispersive model nor wave ray tracing techniques are valid for the shorter period waves in a harbor such as Hilo.

b. Implementation

A possible way of including at least first order effects of dispersion for waves whose length is at least five times the depth is the introduction of a linearized Boussinesq type of wave equation. Peregrine discusses the use of Boussinesq type approximations for waves propagating in one direction over variable topography. Two-dimensional studies using a Boussinesq type approximation have been carried out at Stanford and at Texas A&M University (1975)*. These studies employed a time marching implicit numerical analog version of the Boussinesq equations. However, it is conceivable that this could be employed in the framework of the present finite element model for monochromatic forced wave response.

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* Reid, R. O., A. C. Mungall, J. C. H. Mungall, G. Hebenstreit, Progress Report, "Applicability of Quasi Long Wave Equations to the Numerical Modeling of Dispersive Waves in Two Dimensions." NSF Grant DES 74-12327 A01 Dec 1975.

c. Possible Applications

An interesting application of a dispersive numerical model would be in the investigation of possible anomalous effects produced in distorted physical models for the shorter period waves. By use of such a numerical model, the response of a harbor system could be ascertained for given input for both distorted and undistorted conditions and differences determined.

2. Prototype Data Collection Programs for Future Harbor Studies

a. Discussion

The importance and cost of acquiring meaningful prototype data require the best possible planning and coordination efforts. In this regard, the two following recommendations are made:

1. Numerical Modeling and Planning of Data Collection Programs. The advanced capability of WES in numerical modeling techniques should be used in planning the types, numbers and locations of sensors for prototype data collection. An example is the utilization of the Finite Element Model to investigate the susceptibility of a harbor to long period oscillation response and the deployment of wave sensors at antinodal or other critical positions.

2. Coordination with Field Program. When and where possible, it would be desirable to coordinate a field program and the associated model studies through personnel with responsibility for both efforts. In particular, the advantages are clear of having those responsible for calibrating the model also responsible for planning and participating to a significant degree in the field collection effort.

b. Implementation

Implementation of the above recommendations should be advantageous to all future programs in which field data are collected to evaluate existing prototype conditions and/or to serve as a calibration base for a model test program.

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Reid, Robert Osborne
A consultants review of the Los Angeles-Long Beach Harbors study / by Robert O. Reid, Robert G. Dean, Leon E. Borgman. Vicksburg, Miss. : U. S. Waterways Experiment Station, 1977.
20, 3 p. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; H-77-10)

1. Harbors. 2. Long Beach Harbor. 3. Los Angeles Harbor. I. Borgman, Leon E., joint author. II. Dean, Robert G., joint author. III. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; H-77-10.
TA7.W34m no.H-77-10